# Chapter 9. Review, Limitations and Further Research

In this final chapter, principal findings of the research are reviewed, the limitations of the research are acknowledged and areas for further research are discussed. In 9.1, the significance and major conclusions of this study, in terms of the implications for the Australian beef industry and in terms of some methodological issues respectively, are reviewed. Limitations and areas for further research are discussed in 9.2.

## 9.1 Review of the Study

### 9.1.1 Returns from Alternative Investments in the Australian Beef Industry

In recent years, around $100 million has been spent annually on R&D and promotion in the Australian red meat industries. The money comes from levies paid by producer groups and from government contributions for research. Producers have been questioning the pay-off from these investments. The returns from the investments is also a public policy issue since the coercive powers of government are used to underpin the levy system. Governments should also be concerned about the returns to the expenditure of public funds.

Questions of interest include, among others, the returns from research versus those from promotion, the returns from on-farm research versus those from off-farm research, and the returns from domestic promotion versus those from export promotion. Not only are the total returns from these investments of interest, but also the distribution of the total returns among groups such as cattle producers, feedlotters, processors, exporters, and domestic and export consumers. Identification of benefits to these individual groups will be valuable in aiding policy decisions within the industry.

In this thesis, an equilibrium displacement model of the Australian beef industry was specified and simulated. The demand and supply relationships among different sectors of the industry were represented by a structural model with general functional form. The impacts of new technologies and promotion were modelled as exogenous supply or demand shifts in the relevant markets. Changes in prices and quantities were simulated for each of the exogenous scenarios, and the economic welfare implications were then estimated.

The industry was disaggregated vertically into sectors covering breeding, backgrounding, grass- or grain-finishing, processing, marketing and final consumption. The model included four end products with segregation being made on the basis of grain versus grass finishing and domestic versus export consumption. The model is more disaggregated than existing studies of the Australian beef industry. The model specification enables the analysis of technical changes in individual sectors and promotion in different markets. It also enables the identification of benefits to individual industry sectors. In Chapter 5, an extensive effort was made in compiling a set of base equilibrium prices and quantities for all inputs and outputs representing the average situation for 1992-1997. Market elasticities required in the model were specified based on available empirical estimates, economic theory and subjective judgement. Integrability conditions among these elasticities were also imposed at the base equilibrium for economic consistency.

The model provides a comprehensive economic framework for studying the impacts of various research-induced new technologies and promotion expenditures. In the base model in Chapter 7, twelve investment scenarios were considered relating to new technologies in individual sectors and promotion in export or domestic markets. The study was based on 1% shifts of the supply or demand curves in the relevant markets for the 12 scenarios. For each of these scenarios, total returns in terms of economic surplus change as well as the distribution of total returns among individual industry sectors and consumer groups were estimated.

A complete cost-benefit analysis of investments in research and promotion would include (1) the costs involved in bringing about the initial 1% supply or demand shifts for all scenarios and how these costs are shared among groups, and (2) the total welfare gains in dollars resulting from the initial 1% shifts for all scenarios and how these gains are shared among individual groups. This thesis provides answers only to the second question.

As pointed out in Chapter 7, the percentage distribution of the total welfare change from an investment scenario among industry groups is independent of the amount of the initial shift. In other words, although investing the same amount of money in different scenarios may result in different demand or supply shifts, the shares of the total benefits to individual groups are always comparable among alternative investment scenarios irrespective of the investment costs. From the base model results summarised in Table 7.2 in Chapter 7, the majority of the welfare gains for all 12 scenarios accrue to domestic consumers (48.3% to 65.6%) and cattle producers (19.8% to 33.7%). This is largely due to the significant gross revenues in the domestic retail and cattle breeding sectors and the less than perfect weaner supply and domestic demand elasticities. Overseas consumers and domestic retailers are the other two groups who gain significant shares, receiving 5.1% to 11.7% and 3.6% to 6.8%, respectively, for the 12 scenarios. The shares of benefits to feedlotters, processors, exporters and feedgrain producers are mostly less than 3% in all scenarios, due to the assumption of elastic factor supply in these sectors.

In terms of the farmers' share from alternative investment scenarios, they should generally prefer on-farm research (33.7%, 27.6% and 28.8% shares for Scenarios 1, 2 and 3, respectively) to off-farm research such as R&D in feedlotting, processing and domestic marketing sectors (26.8%, 25.9% and 19.8% shares respectively). An exception is export marketing research which gives farmers 30.2% of the total benefits, even higher than for some on-farm research scenarios.

In terms of promotion versus research, the two domestic promotion scenarios were shown to provide farmers with smaller shares of benefits (23.2% and 23.4%) than all research scenarios (shares of 25.9% to 33.7%) except for domestic marketing research (share of 19.8%). In contrast, export promotion scenarios (shares of 31.3% and 31.6%) were preferred in terms of benefit shares to all research types (shares of 19.8% to 28.8%) except for weaner production research (33.7% share). In addition, while research into grain-finishing (26.8% share) and grass-finishing (shares of 27.6% to 28.8%) were shown to provide farmers with similar benefit shares, overseas beef promotion (shares of 31.3% and 31.6%) would provide farmers with larger shares of total benefits than domestic promotion (shares of 23.2% and 23.4%).

Of course, the preference of a particular industry group for alternative investment scenarios can be very different in terms of absolute monetary gains from that in terms of percentage shares of total benefits, as the total benefits are different for different scenarios. For example, for the same initial 1% shifts in alternative scenarios, the total welfare gains in dollars are much larger from promotion of grassfed beef ($31.55m domestically and $20.38m overseas) and research–induced cost reductions in weaner production ($19.60m) and domestic marketing ($23.88m) than from research-induced cost reductions in backgrounding ($1.74m) and feedlots ($1.13m).

Because information on the costs of bringing about the 1% shifts in the various markets was not considered in this study, the comparison of welfare gains in dollars among alternative investment scenarios can only be made under certain assumptions about the efficiency of investments. For example, if it is assumed that the costs of bringing about the 1% shifts in all 12 scenarios are the same, farmers' preferences can be ranked based on the estimated dollar benefits given in Table 7.2. In this case, grassfed beef promotion in both domestic and overseas markets ($7.36m and $6.45m) was shown to be just as preferable to farmers as weaner production research ($6.61m), while 1% cost reductions in sectors of small value such as backgrounding ($0.51m), feedlotting ($0.29m), export marketing ($0.57) and processing ($1.21m) were shown to provide farmers much smaller dollar returns. As shown in Table 7.3, the ranking of the preferences for farmers was very different in terms of their percentage shares of the total benefits and in terms of their absolute benefits in dollars.

Given that the information on the costs of R&D and promotion investments is unknown, the initial percentage and absolute shifts required in all 12 scenarios that are necessary to achieve the same dollar benefits as from Scenario 1, in total and to farmers respectively, were also provided in Tables 7.4 and 7.5 of Chapter 7. These results can be used, along with external information on the costs of bringing about these required initial shifts, to decide which scenario is preferable. For example, in order for farmers to be indifferent about investing their money in weaner production research, feedlot research or domestic grassfed beef promotion, the required investments in reducing the cost of weaner production by 1%, or reducing the cost of feedlot inputs by 22.79%, or increasing the domestic consumers' willingness to pay for grassfed beef by 0.90%, need to be the same.

In summary, the equilibrium displacement model developed in this study provides a rigorous and consistent economic framework for analysing total welfare changes and their distribution among industry groups from various exogenous changes affecting the Australian beef industry. This information on benefits can be used in a cost-benefit analysis of different investments along with information about the costs of bringing about the initial shifts in demand and supply functions. It can be used for individual R&D or promotion project evaluations, or for comparisons among broad types of research and promotion investments, if costs of alternative investment scenarios are available. It can also be used to simulate the effects of various government interventions such as tax or price policies. It is disaggregated both vertically and horizontally to a greater extent than previous models, thus enabling studies of exogenous changes occurring at individual industry sectors.

### 9.1.2 Some Methodological Issues Addressed

***Functional Forms, Types of Exogenous Shifts, and Errors in EDM Results***

There have been concerns in the EDM literature about the assumptions relating to functional forms and types of exogenous shifts of demand and supply curves (for example, Alston and Wohlgenant 1990; Hurd 1996; and Lindner and Jarrett 1980). In Chapter 3, the issues about functional forms and the nature of exogenous shifts in EDM applications were re-examined and clarified using an analytical approach. In particular, the assumptions required for the EDM results and the resulting economic surplus changes to be exactly correct were clarified. Analytical expressions for the errors when these assumptions are not met were derived. These error expressions enable the identification of determinants, in terms of the demand and supply parameters, of the sizes and directions of the errors in both the EDM estimates of price and quantity changes and the resulting measures of welfare changes.

The results derived in Chapter 3, also published in Zhao, Mullen and Griffith (1997), indicate that when the exogenous shifts considered in EDMs are small and when parallel exogenous shifts are assumed, the functional forms of the demand and supply curves are irrelevant in obtaining good approximations of both the price and quantity changes and the economic surplus changes. However, the results also indicate that, when proportional shifts are assumed, significant errors are possible in the measures of welfare changes from using the wrong functional forms. Finally, since the results in Chapter 3 showed that, in the case of parallel shifts, only local linearity is required of the demand and supply curves to have the EDM results exactly correct, the restriction in some past studies that supply curves had to have elasticities greater than one in order to have positive intercepts was shown to be unnecessary.

***Measures of Economic Surplus Changes in Multi-Market Models***

As has been recognised in the literature (for example, Slesnick 1998), complications arise regarding the measurement of economic welfare in multi-market models. In particular, care needs to be taken when there are multiple sources of equilibrium feedback in multi-product models (Thurman 1991a, 1991b; Just, Hueth and Schmitz 1982, p192; Alston, Norton and Pardey 1995, p231-234). This occurs, for example, when two products are related in both production and consumption. As a result, a single source of exogenous shock will induce endogenous shifts in both the supply and demand curves in the two markets. In this case, both the producer's profit function and the consumer's expenditure function involve multiple price changes.

In Chapter 6, the economic welfare implications for the various industry groups for the 12 exogenous shift scenarios were examined through the profit or expenditure functions and the associated integrals of supply or demand functions. These welfare changes were also related to graphical areas in the relevant markets. Eleven industry groups were identified in the model. They relate to factor suppliers in various sectors and final beef consumers. For ten of these groups, there is only a single price change in the relevant profit or expenditure functions. In other words, there is only one source of feedback in each of these ten markets. For these ten groups, the economic surplus changes were used as welfare measures and they were measured straightforwardly as areas off the exogenously fixed supply or demand curves. Based on the results shown in Willig (1976) and Hausman (1981) for the single market models, as the whole trapezoid areas of welfare changes were of interest in this study and the equilibrium shifts were small, the consumer surplus changes are expected to be good approximations to the preferred compensating or equivalent variation measures.

However, the two domestic beef products were assumed to be related in both supply and demand. The domestic consumers' decision problem involves two price changes and this is the case described by Thurman (1991a) as having two sources of equilibrium feedback. It was shown in Chapter 6 that, when integrability conditions are imposed on the Marshallian elasticities at the base equilibrium, the economic surplus measures are uniquely defined and path independent. Under the integrability conditions, the economic surplus changes can be uniquely measured either through the general equilibrium curves in a single market or via the partial equilibrium curves in individual markets.

The derivations in Chapter 6 also implied that, when integrability conditions are not met, the first-order terms ($\mathbf{O}(\lambda)$) of the economic surplus measures may still be path independent and equal to the first-order terms of the compensating or equivalent variation measures. The integrability conditions may only affect the economic surplus measures at the second order terms ($\mathbf{O}(\lambda^2)$). Since changes in economic surplus (trapezoid areas) are of the first-order magnitude ($\mathbf{O}(\lambda)$), as long as the considered equilibrium displacements are small ($\lambda$ is small), failure to satisfy integrability conditions may not result in significant errors in using economic surplus changes as welfare change measures. However, if the second-order measures of triangular 'deadweight loss' are of interest in a policy study, integrability conditions are vital and violation of them could result in significant errors. This is consistent with the empirical observations in LaFrance (1991), who showed that the errors were insignificant in the estimation of the trapezoid area of economic surplus change when using *ad hoc* linear models.

Finally, it has been recognised in the literature (Just, Hueth and Schmitz 1982, p469; Alston, Norton and Pardey 1995, p232) that, when integrability conditions are satisfied, there are two alternative ways of calculating the welfare effects: measuring the total welfare change off the general equilibrium curves in the single market where the initial shift occurs, or measuring the individual welfare effects off the partial equilibrium curves in individual markets and adding up. Thurman (1991a) examined the welfare significance and insignificance of the economic surplus areas off the general equilibrium curves in a single market when multiple sources of equilibrium feedback exist. In particular, he showed that the area off the general equilibrium demand or supply curve individually does not measure welfare to any identifiable group, but the sum of the two areas measures the total welfare change. In this chapter, it was pointed out that, in the case of multiple channels of feedback, caution also needs to be taken in measuring economic surplus areas off partial equilibrium demand or supply curves. When two markets are related through more than one source, the economic surplus change to the producers or the consumers should be measured sequentially in the two markets and then added up; that is, the surplus change based on the (same) *initial* partial equilibrium curve in the first market plus the surplus change based on the (same) *new* partial equilibrium curve in the second market. It is wrong to calculate changes in surplus areas based on different partial equilibrium curves in the same market, as has been done in some past studies. It was shown with an example that the error in doing so could be significant (of the order of $\mathbf{O}(\lambda)$).

***Sensitivity Analysis in EDM Applications -- A Stochastic Approach***

Sensitivity of EDM results to uncertainty in market parameters is currently receiving considerable attention in the literature (Davis and Espinoza 1998; Griffiths and Zhao 2000). The sensitivity of the estimated equilibrium displacements and the consequent welfare measures to model parameters has often been questioned. Risks are often involved in the success of research programs. There is also uncertainty in the industry's response to new technologies and consumers' response to promotions, especially in *ex ante* evaluations, which implies uncertainty in the extent of initial supply or demand shifts. However, most of the concern has been with respect to the required market elasticities. These market parameters have often been chosen based on available empirical estimates, economic theory and subjective judgement. Often, limited published estimates are available for some elasticities and substantial subjective judgement has to be exercised in choosing these parameters. It has been a common practice in EDM applications to run some discrete sensitivity analysis, but comprehensive sensitivity analysis has proven to be frustrating when several uncertain parameters are involved.

In Chapter 8, a simulation approach to a comprehensive sensitivity analysis in EDM applications was proposed (published in Zhao, *et. al.* 1999). Using the proposed approach, the uncertainty in all elasticities can be represented with subjective probability distributions. Any deterministic equality or inequality restrictions or statistical correlations among different parameters can be easily imposed on the joint distribution. The implied probability distributions for welfare measures can be obtained via Monte Carlo simulation. These probability distributions characterise the uncertainty in the welfare estimates and enable the calculation of the most likely values, standard deviations and 95% probability intervals for welfare measures. Any policy-related probabilities and probability intervals can also be calculated to reflect confidence about any policy-related conclusions.

The approach was applied to the current model to study the sensitivity of base results to uncertainty in all market elasticities. For a specified joint subjective distribution for all market parameters, the means, standard deviations and 95% probability intervals for some of the welfare measures in the base results in Table 7.2 were given in Table 8.5. The statistical results in Table 8.5 provide an indication of the scope of possible variations in the welfare implications from the base results, given the specified uncertainty in elasticities. Some policy-relevant probabilities and probability intervals which represent the robustness of some policy conclusions in the base model were also presented in Chapter 8. Preferences among alternative investment scenarios were shown to be robust in terms of the *percentage shares* of the total benefits to individual groups. However, the comparison in terms of the *absolute* dollar benefits, under the assumption of equally efficient investments in the 1% shifts in all sectors, was shown to be quite sensitive to the assumed parameter values. For example, it was shown that even if there is a 100% probability that farmers will gain a larger share of the total benefit from weaner research (Scenario 1) than from domestic grassfed beef promotion (Scenario 12), the preference in terms of their absolute benefit is much more uncertain. If it is assumed that the costs in bringing about the 1% cost reduction in weaner production and the 1% increase in willingness to pay for domestic grassfed beef are the same, there is a 56% probability that farmers will gain more in dollars from weaner production research than from domestic grassfed beef promotion, but 44% probability for the opposite.

Some useful measures for the sensitivity of results to individual parameters were also proposed in Chapter 8, using estimated response surfaces. A mean sensitivity elasticity measures the average percentage change of a welfare measure due to a 1% increase in a particular parameter, *ceteris paribus*. The mean error in a welfare measure due to uncertainty in a particular parameter was proposed to measure the importance of a parameter taking into account the fact that levels of uncertainty (or knowledge) about different parameters are different. For example, based on the results in Tables 8.6 and 8.7, even though the sensitivity elasticities for input substitution and product transformation elasticities ($\sigma$'s and $\tau$'s) were shown to be much smaller than those for most of the factor supply and beef demand elasticities ($\varepsilon$'s and $\eta$'s), the mean errors in welfare measures resulting from uncertainty in $\sigma$'s and $\tau$'s, *ceteris paribus*, were shown to be just as large or even larger than the errors due to uncertainty in $\varepsilon$'s and $\eta$'s. In empirical applications, there are often more empirical estimates for $\varepsilon$'s and $\eta$'s than for $\sigma$'s and $\tau$'s. As a result, the chance of making larger percentage errors in the choice of values for $\sigma$'s and $\tau$'s is much larger than in the choice of $\varepsilon$'s and $\eta$'s.

## 9.2 Limitations and Further Research

### 9.2.1 Partial Equilibrium versus General Equilibrium Models

The model developed in this study is a partial equilibrium model that concentrated on the interaction among different sectors within the Australian beef industry. All other industries outside the beef industry were assumed unaffected by changes in the beef industry. The economy-wide implications, including interaction with other agricultural industries, were ignored. In reality, the beef industry is related in production to other livestock and crop industries such as the sheep industry and the wheat industry. Also, most meat consumers regard beef, lamb, chicken and pork as close substitutes. Thus the beef industry is also related to the lamb, chicken and pork industries through demand. An innovation in the beef industry will result in a fall in beef prices in the first instance As second round effects, the supply of lamb and the demand for lamb, chicken and pork will also be affected, which results in price changes in these other industries. These changes in other industries will also feedback to induce further changes in the beef industry. A model that takes account of these interactions with other meat industries is of a more general equilibrium nature and would be more realistic in the context of the current structure of Australian agriculture.

Development of a complete general equilibrium model would require more resources than were available for this thesis. In addition to the increased data and resource requirements in building such a general equilibrium model, an important restriction comes from the complication involved in the welfare measures in multi-product models. As pointed out above, the welfare measures are complicated when more than two sources of equilibrium feedback are involved in multiple product situations (Thurman 1991a; LaFrance 1991; Alston, Norton and Pardey 1995; Slesnick 1998). In the partial equilibrium model in this study, although multi-products were involved, there is only a single source of equilibrium feedback in the decision problems for the majority of the industry groups and the welfare measures are straightforward for these groups. The only situation that involved more than one source of feedback related to domestic consumers where two price changes were involved in the domestic consumers' decision making problem. As shown in Chapter 6, in the case of two price changes, if integrability conditions are imposed on the Marshallian elasticities, the consumer surplus changes are uniquely defined and can be measured sequentially as the trapezoid areas off the partial equilibrium demand curves in the two markets. They were expected to be good approximations to the exact compensating or equivalent variation measures, as long as the equilibrium shifts considered are small and only one exogenous change is considered at one time.

However, for more general equilibrium models that involve more than two products related in both demand and supply, or for equilibrium models that involve multiple technical changes and market distortions, the off-the-curve economic surplus measures as demonstrated in Chapter 6 become more complicated or impossible. In these cases, the estimated changes in prices and quantities using EDM will still be good approximations, but the welfare measures will be difficult. An analytical approach that is more theoretically sound would be necessary. Martin and Alston (1994) and Alston, Chalfant and Piggott (1999) have used an exact approach for measuring the impacts of technical changes and promotions. It involves the explicit specification of profit and expenditure functions and the inclusion of technical change and promotion variables in these functions. This is a more theoretically consistent approach that can be used for more general equilibrium issues involving multiple sources of feedback and simultaneous exogenous changes. This approach would be appropriate in examining the interaction between changes in the beef industry and other meat industries. However, the possibility of using this approach for studying the sectoral interaction within the beef industry, among both vertically and horizontally disaggregated sectors as in this model, and for estimating the welfare distributions among these individual groups, is questionable. Also, the joint profit function approach cannot provide separate producer welfare measures to individual industries such as the beef industry. The change in the joint profit function would give the welfare change, for example, for beef, sheep and crop producers as a whole. Perhaps, a two-stage approach using both frameworks might be possible in order to study both the general equilibrium interaction of the beef industry with other meat industries and the sectoral and welfare distributional effects to individual sectors within the beef industry.

### 9.2.2 Dynamics

As reviewed in detail in Section 2.5.5, the equilibrium displacement modelling approach used in this study is a comparative static analysis in which two snapshot situations are compared. The new technologies in all sectors and promotion in different markets have been assumed to result in the initial shifts in the supply or demand curves instantly after the investments. In reality, while some promotion campaigns and some nutritional or management R&D may have prompt effects, a longer time lag is often involved in the effects of more basic research. Often, there are time lags between the R&D investments, the research outcomes and the adoption of the technology. Adoption and disadoption of a technology is also a long process following certain patterns. Research costs including maintenance costs are often incurred over a period of time. Similarly, the promotional costs and the impacts on the consumers' willingness to pay may also occur over a period of time.

In addition, it often takes several years for an industry, especially the cattle industry, to completely adjust to an initial shock to reach a new equilibrium. Just, Hueth and Schmitz (1982, p65-66) illustrated how to measure the annual welfare implications for the years after the initial shock and before the new equilibrium, using supply curves of different lengths of run. In this study, it was assumed that a medium-run time frame is needed for the beef industry to fully adjust to the initial shocks, and medium-run elasticities have been chosen for the base model. Thus, based on the length-of-run analysis by Just, Hueth and Schmitz (1982), the welfare gains estimated in the current study relate to the *annual benefit for the years on and after reaching the new equilibrium*. The annual benefits for the years during the equilibrium adjustment can be calculated using shorter time-run elasticity values associated with the periods between the starting point and each year.

A complete evaluation of a research or promotion investment and any comparison among alternative investment scenarios should take into account the sequence of all costs and benefits over time in relation to the above factors. These benefit and cost flows can then be summarised using net present values (NPV) or internal rates of return (IRR) with the appropriate discount rate.

### 9.2.3 The Competitive Structure of the Australian Beef Industry

The assumptions made in this study have implied that the Australian beef industry is characterised with perfectly competitive behaviour along the production and marketing chain. This has meant that in the specification of the equilibrium displacement model, prices are assumed to be equal to marginal costs. Once the assumption of perfect competitive market is relaxed, the estimated returns from R&D and promotion are expected to be different (Huang and Sexton 1996; Alston, Sexton and Zhang 1996).

There have been increasing concerns about the competitive structure of the Australian food marketing chain (ACCC 1999; Australian Parliament 1999). Empirical evidence of the Australian meat industries (Chang and Griffith 1998; Zhao, Griffith and Mullen 1998; Hyde and Perloff 1998) indicated that the domestic beef market may be consistent with competitive behaviour on the selling side. But several submissions to the recent Joint Select Committee on the Retailing Sector (e.g. NFF 1999) suggested that this may not be the case on the buying side in the domestic market. Zhao, Griffith and Mullen (1998) also showed some evidence that the export market for Australian beef may not be competitive due to policy interventions in the US and Japanese markets.

The rapidly changing structure of the Australian beef industry has highlighted the need for some detailed case studies about the competitive behaviour of different components of the beef marketing chain, and the implication of this for evaluating returns from R&D and promotion investments.

### 9.2.4 More on the Uncertainty in Elasticities

As discussed in Chapter 8, very limited information is available about the values of some market elasticities required in the study, and the estimated economic welfare changes can be sensitive to the choice of these parameters. The proposed stochastic approach to sensitivity analysis allows the uncertainty in parameters to be represented with subjective probability distributions. However, the specification of the parameter distributions in Chapter 8 has been rather crude.

A finer approach in eliciting the subjective probability distributions for uncertain parameters could start from a more thorough review of relevant empirical evidence and surveys of expert opinions on the possible values of elasticities. Prior distributions can be obtained from the histogram of available empirical estimates and the expert surveys. Ideally, if sample data are available, an econometric model can be specified. Then a more formalised Bayesian approach can be utilised to combine the prior distribution and the current sample information using the econometric model to derive the posterior distribution for the parameters and the resulting welfare measures.

Further research is also warranted into the methodology for studying the importance of individual parameters. A quadratic response function that approximates the relationship between a model outcome and all parameters to the second order would give a finer approximation than the double-logarithmic function used in Chapter 8. In addition, the statistical measures for the sensitivity of model results to individual parameters (for example, the 'sensitivity elasticity' and the 'expected error' of not knowing a particular parameter as proposed in Chapter 8) may be formalised in a decision theory framework.

### 9.2.5 A Complete Benefit/Cost Framework

In this thesis, 1% shifts of the relevant supply or demand curves for alternative investment scenarios were simulated. The total welfare benefits and their percentage distributions among the various industry groups were estimated. However, the investment costs required to bring about the 1% initial shifts, or the issues regarding the efficiency of the R&D and promotion investments, were not examined. In other words, this study only provides part of the information for a complete cost-benefit analysis of alternative investments in the Australian beef industry.

However, the model specified in this study has provided a framework for a complete cost-benefit analysis once the data on the investment efficiency or costs are available. For example, if the model is to be used for evaluation of a particular research program, the technical aspects of the research or new technology can be closely studied to estimate the direct impact in terms of productivity change or cost reduction. The implied amount of supply shift in the relevant market can then be estimated and used as input to an EDM (for example, Lemieux and Wohlgenant 1989). Probability of research success, rate and pattern of adoption and the flow of research costs can also be accounted for. A similar procedure is required for assessing a particular promotional program, which may start at quantifying its direct effect on consumers' perception of the products.

If the model is to be used for evaluation and comparison of broad categories of research-induced technologies and promotion to address general policy issues in priority-setting, information about investment efficiency is necessary. Eliciting the expected amounts of supply or demand shifts based on the same amount of monetary investments in different scenarios would be difficult. Econometric models may be required for estimating such direct impacts (Scobie, Mullen and Alston 1991; Mullen and Cox 1995; Cox, Mullen and Hu 1997). Data on research expenditures and the associated productivity, or promotion expenditures and the changes in demand, would be required. The resulting benefits from alternative investment scenarios will be comparable when the initial shifts in all scenarios relate to the same investment cost. In addition, the final appraisal of alternative investment scenarios will need to take into account not only the economic objectives in terms of efficiency, but also the social objectives and even environment concerns.

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